DEFECT COUPLING: THE LAST FRONTIER IN PREDICTING THE STRENGTH, LIFE, AND DURABILITY OF FIBER REINFORCED COMPOSITE LAMINATES

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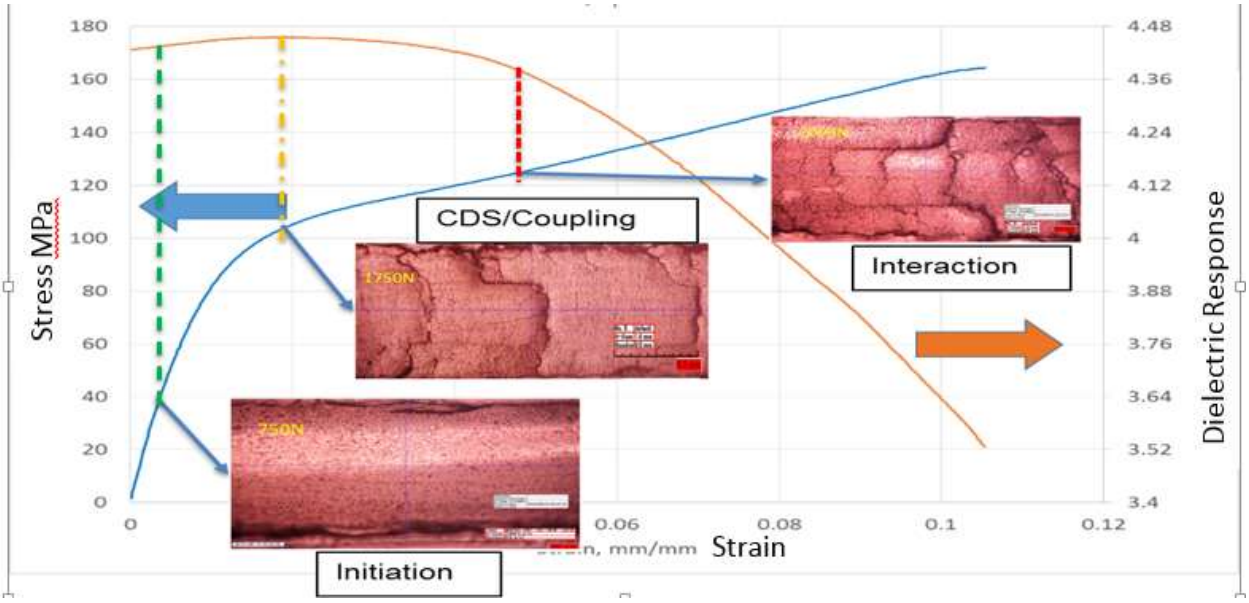
After more than 30 years of careful experimental investigation and exhaustive development of discrete damage analysis methods including integrated computational mechanics methods, our community knows a great deal about how discrete defects such as matrix cracks and defect growth (e.g. delamination) can be predicted. But many practical situations controlled by laminated multiaxial composite structures, the loss of performance and "sudden death" end of life is controlled by defect coupling which becomes a precursor to fracture plane development. Until recently, analysis methods to address such complex interaction and coupling of multiple defects and experimental methods of following the details of such interaction sequences as a foundation for understanding and model validation were not available. We believe that this barrier has been largely removed by recent work.



The figure illustrates the direction of our discussion. The stress-strain curve was recorded for tensile loading of a (+45,-45)s glass epoxy laminate loaded to failure. The insets show edge replica recordings of the damage development during this large deformation-to-failure test, including matrix cracking (and saturation) followed by crack coupling leading to fracture. The red curve presents measured values of through-thickness dielectric permittivity, which we have discovered reverses its direction of change with strain (from increasing to decreasing) exactly when defect coupling begins. Our discussion will present our efforts to interpret these results and to use our understanding to construct the first discrete defect simulation models followed by multiphysics modeling to predict this behavior (for the first time, to our knowledge). These and other examples are used to discuss our current level of understanding of this coupling as a precursor to the "beginning of the end" of performance of structural composite laminates